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Editorial

Electrification of the car – Will the momentum last? Introduction to the special issue

1. Introduction

The transport sector is one of the main contributors to both greenhouse gas emissions and local air pollution. Therefore it is clear that the sector has to reduce its environmental impact. Both technological and broader system innovations are needed for this (Banister et al., 2011). At an EU level, an ambitious goal has been set for reducing GHG emissions, namely by 60% in 2050 (EC, 2011). To achieve this goal for transport, most attention is given to passenger transport and especially passenger vehicles. Because other modes of transport, such as heavy-duty freight transport and aviation, are seen as more challenging in terms of reducing emissions, passenger transport should become virtually zero-emission by 2050 (EC, 2011).

Even though it is widely acknowledged that a transition to zero-emission passenger transport is necessary, it is not so clear which drivetrains and fuels are to be used for this. Many suggest that the traditional combustion engine needs to be replaced by an electric engine (Ogden and Anderson, 2011; IEA, 2010), which can be powered by either a battery or a (hydrogen[1]) fuel cell. Because in all cases there is still a need for primary fuel production, the well-to-wheel environmental impacts should always be considered in assessing these alternatives (Offer et al., 2010).

The recent history of innovation in the automotive industry has shown many 'cars of the future', but no apparent winner has emerged yet. Even more so, both car manufacturers and policy makers have often shifted their attention from the one alternative fuel to the other. This phenomenon has come to be known as the 'fuel du jour' syndrome (Sperling and Gordon, 2009). For instance, in the 1970s and '80s, considerable attention was given to hydrogen powered vehicles. In the first half of the 1990s, battery-electric vehicles were given most attention, but these proved no success either. Next, biofuels and hydrogen took over as the most promising option to replace fossil fuels. In the meantime, the relatively silent rise of hybrid-electric vehicles (Dijk et al., 2013), notably in Japan, paved the way for the comeback of the battery-electric vehicle; car manufacturers gained experience with electric drivetrains and consumers got used to the idea of driving an electric vehicle.

Since the late 2010s, pure battery-electric vehicles have been available on the market and they have reached market shares of about 1% in many countries worldwide (Sierzchula et al., 2014). Even

[1] Hydrocarbon fuels can also be used in a fuel cell to generate electricity, but this would not be a zero-emission solution.

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though these sales figures are quite modest, they do show that battery-electric vehicles have moved beyond the pilot and demonstration phase. Furthermore, all major car manufacturers offer a pure battery-electric vehicle or a plug-in hybrid electric vehicle. It thus seems that the automotive industry has picked its winning technology and that battery-electric vehicles, including plug-in hybrids, are the industry's answer to societal concerns about the unsustainability of passenger cars.

Despite all these signals, there is no certainty that automakers will continue their efforts. One could argue that the adoption of electric vehicles by firms and individual consumers is largely driven by financial incentives such as tax breaks and cash subsidies. It is doubtful whether governments around the world are willing and able to continue these subsidies until electric vehicles are truly competitive in terms of price and performance. Furthermore, current and anticipated norms for vehicle emission are the main drivers for car manufacturers to develop and market zero-emission vehicles. Whether or not manufacturers will continue to offer electric vehicles thus also depends on future norms for car technology.

2. A momentum for electric vehicles?

This special issue brings together six articles addressing a transition to electric mobility. These were selected from papers presented at an international workshop in November 2012, organized jointly by Delft University of Technology and Utrecht University. This workshop focussed on the socio-economic aspects of the transition to electric mobility and more specifically on the question whether the current momentum for electric vehicles can and will last.

The term "momentum" refers to the critical mass of actors supporting a transition and the acceleration of related socio-technical developments. The presence of a critical number of agents supporting the transition is likely to attract new actors, which in turn can result in continuous technological improvements and improved economic viability of electric mobility. Momentum may even include the possibility that developments become unstoppable so that from this moment on the transition is inevitable. The fact that earlier attempts to introduce electric vehicles at a large scale failed can be interpreted as insufficient momentum being generated at the time, due to too few agents being involved or a too slow speed of relevant innovations.

To generate momentum for electric vehicles, at least four stakeholders are crucial, namely car manufacturers, consumers, governments at multiple scales, and providers of infrastructure (Bakker et al., 2014). A rough divide is visible in the literature between studies of the supply-side and associated policies and those of the demand-side and related policies. Some studies have dealt with, for instance, the varying responses of car makers to governmental policies, while others address firm's intrinsic motivations to develop electric vehicle technology or new business models. Consumer-oriented studies have, for example, examined how much consumers are willing to pay for electric vehicles and how public policies can contribute to their diffusion. Such policies may provide financial incentives for consumers, but also free-parking for electric vehicles or the use of bus lanes.

3. Papers in this issue

The six articles that were selected for this special issue adopt complementary empirical and theoretical perspectives on electric mobility. The studies range from case studies of regional attempts to support the transition to an agent-based model of the global automotive industry's response to environmental regulations. Still, they all revolve around the central question: is enough momentum for electric vehicles generated to make this transition happen and what role can public policies play?

The first contribution, by Haley (2015), relates to the question whether specific institutional settings are beneficial for the development of electric mobility. The author argues that Québec would be the ideal place for an electric mobility system to develop, because of its large share of hydro power in electricity generation and the transformative potential that this may bring about. A case study confirms that the hydro regime enabled the development of an electric vehicle innovation system. Québec's large hydro sector has over the past 40 years led to organizational and institutional resources that helped to legitimize many early stage innovations in batteries and electric vehicles. However, the

study concludes that the hydro regime in Québec contributed to a nascent electric mobility sector, but lacked relevant resources, such as automotive expertise, to make electric vehicles a success.

Nykvist and Nilsson (2015) start with a similar question. They investigate, in a location-specific case study, why electric vehicles are not taking off in Stockholm despite favourable local conditions. Sweden, and Stockholm in particular, have proven to be environmental frontrunners in many respects, which would suggest that electric mobility could easily develop there. However, EVs are hardly supported and adopted in Stockholm. The authors analyze the developments at the niche, regime and landscape levels. They find that there is limited experience with, and limited development of knowledge on fully electric vehicles in niches, partly because the strong automotive industry in Sweden (the "regime") favours plug-in hybrid vehicles over battery-electric vehicles. This limited niche activity leads to enduring misconceptions about the technology. Furthermore, strong policy signals in favour of battery-electric vehicles are missing because policy makers dislike supporting specific technologies. This aversion is caused by the former Swedish support for ethanol, which is now commonly perceived as having been a major policy mistake.

In the third paper, Budde et al. (2015) study the role of car manufacturers. They investigate the differences between their innovation and communication strategies. The study starts with the observation that car manufacturers have often raised expectations by announcing the marketing of alternative fuel vehicles, such as the hydrogen car. When these optimistic expectations were not met in the proposed timeframe, optimism eventually turned into disappointment. Such developments in the past can explain the phenomenon of technological hypes. This pattern is clearly visible in the case of hydrogen fuel cell vehicles, and less so in the case of hybrid electric vehicles. The difference is explained in this paper by considering the unique characteristics of these two technologies. Car manufacturers can commercialize hybrid vehicles without having to rely on others to build a new fuel infrastructure. They therefore do not need to voice optimistic expectations about these vehicles. In contrast, they depend on others when trying to commercialize hydrogen fuel cell vehicles, as a new hydrogen refuelling infrastructure is required. The authors conclude that there is a clear incentive for manufacturers to raise strong expectations given that the intended innovation depends very much on the parallel development of a new infrastructure.

Van der Vooren and Brouillat (2015) develop a model to study the complex interactions between car manufacturers' strategies and consumers' choices under different regulatory conditions. They use an original agent-based model to simulate the outcomes of several policies and policy packages that may increase the adoption of clean cars. The important indicators presented in this study relate to automotive CO_2 emissions, the impact on public finance, and public incentives for the car industry to invest in clean cars. They find that an effective policy package consists of awarding a rebate to radically new technologies and simultaneously imposing a CO_2 (sales) tax on the incumbent technology. They further discover that specific policy mixes can increase the burden on public finance without having positive effects in terms of CO_2 emissions reduction or development of clean technologies. This stresses the importance of carefully designing and mixing policies in this field.

Mazur and colleagues (2015) study current policies in Germany and the UK that aim to stimulate the development of an electric car system. They show that such policies go hand-in-hand with industrial competitiveness goals. Since the private car sectors in both countries are quite different, the envisaged future car regimes in both countries are also quite distinct. The authors derive possible transition pathways from the policy targets for low emission vehicles in both countries and assess whether current policymaking in Germany and the UK supports these. They find that a 'reconfiguration pathway' would be most likely given the policies in the UK, which support the local automotive industry to gain an important role as suppliers to the future electric car industry. In the German case they find that a 'transformation pathway' best matches the current policies, as German policymakers aim to preserve the existing automotive manufacturers and suppliers, which suggests a transition that is less disruptive. The study warns, however, that this German transition pathway may not be able to meet national and international road transport emission targets in time.

In the final contribution, Augenstein questions the impact of electric vehicles on the mobility system. She addresses the question whether the introduction of electric vehicles should merely be regarded as a process of technological substitution or as part of a potential broader transition. She

therefore studies the 'transformative capacity' of the electric vehicle in relation to the stability of the current mobility regime. She identifies two aspects of EVs that may be important in this respect. First, the 'mis-fit' of EVs with the current mobility regime may change our way of thinking about the role of the car and of car ownership. Second, large-scale diffusion of EVs can have an impact on the electricity system, which may increase the likelihood of a wider energy transition. This is suggested by many current EV drivers demanding electricity from renewable sources. Moreover, EVs can offer a buffer for intermittent electricity supply from renewable energy sources. Augenstein concludes that currently the adaptability of the mobility system is low and that the EV niche is captured by regime incumbents, indicating that a true mobility transition is not yet taking off.

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